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Used Fuel Disposition Campaign

Evaluation of the Frequency for Gas Sampling for the High Burnup Confirmatory Data Project

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5 Questions and a Strategy

1. **What are the possible gases?**
2. **Could detection limits impact the gas sampling frequency strategy?**
3. **Could gases segregate within the cask?**
4. **What are the degradation mechanisms that could change the gas composition?**
5. **Can changes in gas composition provide information about these degradation mechanisms that may be useful for informing component performance predictive capabilities?**

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Gas Sampling Frequency Strategy

Questions

1. **What are the possible gases**
   - **Expected - helium backfill at 2.2 atm**
     - ***233 moles (930 g) in project cask***
   - **Possible – residual water vapor and/or its decomposition products (H_2 and O_2) at less than 0.25 volume % (suggested limit in NUREG-1536).**
     - ***Equivalent to 10.5 ml of liquid water.***
   - **Not expected – residual air, residual water vapor in excess of 0.25 volume %, fission product gases**

Table 2-2. Calculated ^{85}Kr and ^{134}Xe content of the 25 Sister Rods at possible loading and unloading times

Assembly				Rod	2/1/2016	2/1/2027	Stable
ID	**Enrichment**	**Burnup (MWD/MTU)**	**Cooling Time (years)**	**ID**	**^{85}Kr (Ci)**	**^{85}Kr (Ci)**	**^{134}Xe (g)**
30A	4.55	52.0	5.4	G-9	22.540	11.092	4.255
				K-9	22.496	11.072	4.244
				D-5	22.924	11.284	4.351
				E-14	22.980	11.312	4.365
				P-2	21.432	10.548	3.984
5K7	4.55	53.3	9.9	P-2	16.472	8.108	4.119
				C-5	17.800	8.760	4.562
				K-9	17.152	8.440	4.343
				O-14	16.852	8.296	4.244
6U3	4.45	52.7	11.7	I-7	15.164	7.464	4.360
				M-9	15.312	7.536	4.416
				K-9	15.216	7.488	4.380
				L-8	15.328	7.544	4.422
				O-5	15.928	7.840	4.655
				M-3	15.792	7.772	4.603
				P-16	14.180	6.980	3.993
3F9	4.25	52.3	14.4	N-5	12.620	6.212	4.361
				D-7	12.288	6.048	4.210
				P-2	11.692	5.756	3.943
3D8	4.20	54.9	17.4	E-14	10.992	5.412	4.717
				B-2	9.796	4.824	4.044
3A1	4.00	50.0	21.4	B-16	7.236	3.562	3.884
				F-5	7.572	3.726	4.124
F35	3.59	57.9	26.9	P-17	5.572	2.743	4.620
				K-13	5.572	2.743	4.620

Questions

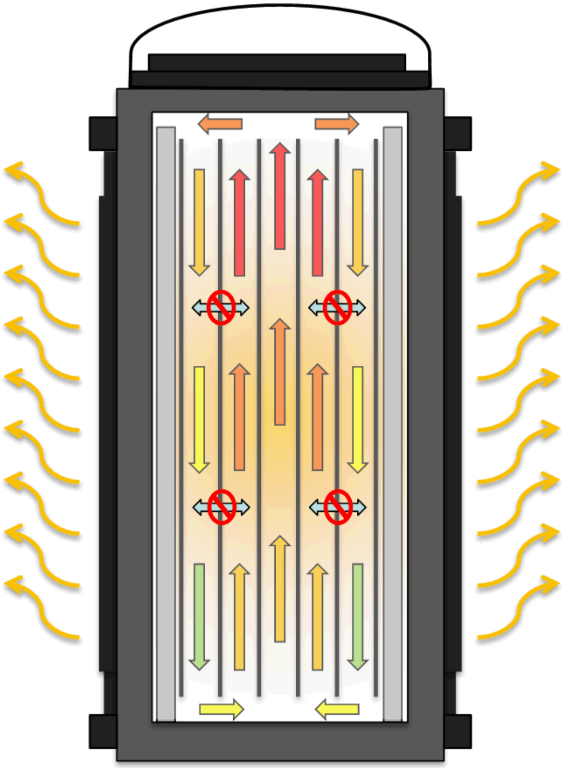
2. **Could detection limits impact gas sampling frequency strategy?**

- **No**
  - **Evaluated ^{85}Kr, ^{134}Xe, H_2O, H_2 and O_2**
  - **Modern detection efficiency is orders of magnitude better than needed for all of these gases**
    - ***^{134}Xe can be measured using modern gas mass spectroscopy with a detection efficiency as low as 10 ppb. Release of 1% of ^{134}Xe from a single rod would result in a mass concentration of 46 ppm.***
    - ***^{85}Kr can be measured using gamma spectroscopy, mass spectroscopy, and liquid scintillation with a detection efficiency on the range of one pCi/cm^3. Release of 1% of ^{85}Kr from a single rod would result in a concentration of 22 nCi/cm^3.***
    - ***H_2O detection limits are in the ppm-range. 0.25% water vapor equates to 11 parts per thousand.***

Questions

3. **Could gas segregate due to gravitational settling or thermal diffusion?**

- **No**
  - **Minimal gravitational settling may occur immediately after gas release, but a compositional gradient cannot be maintained even in a static gas column, let alone in a cask with a convecting gas column.**
  - **Significant compositional gradients due to thermal diffusion require comparable initial concentrations of the two gas components, large thermal gradients, and a geometry that allows gas diffusion between the rising and falling arms of the convection cells. None of these exist in the project cask.**



Questions

4. What are the degradation mechanisms that could change the gas composition?
   - Corrosion of internal components can consume H_2O and O_2
   - Presence of water logged components can increase H_2O and O_2 concentration
   - Breach of cladding can release fission gases - not expected
     - *Early degradation mechanisms: DHC, fission product attack, creep, oxidation*
     - *Long-term degradation mechanisms: fuel restructuring/swelling, hydride embrittlement and reorientation*

Questions

5. **Can changes in gas composition provide information about these degradation mechanisms that may be useful for informing component performance predictive capabilities?**

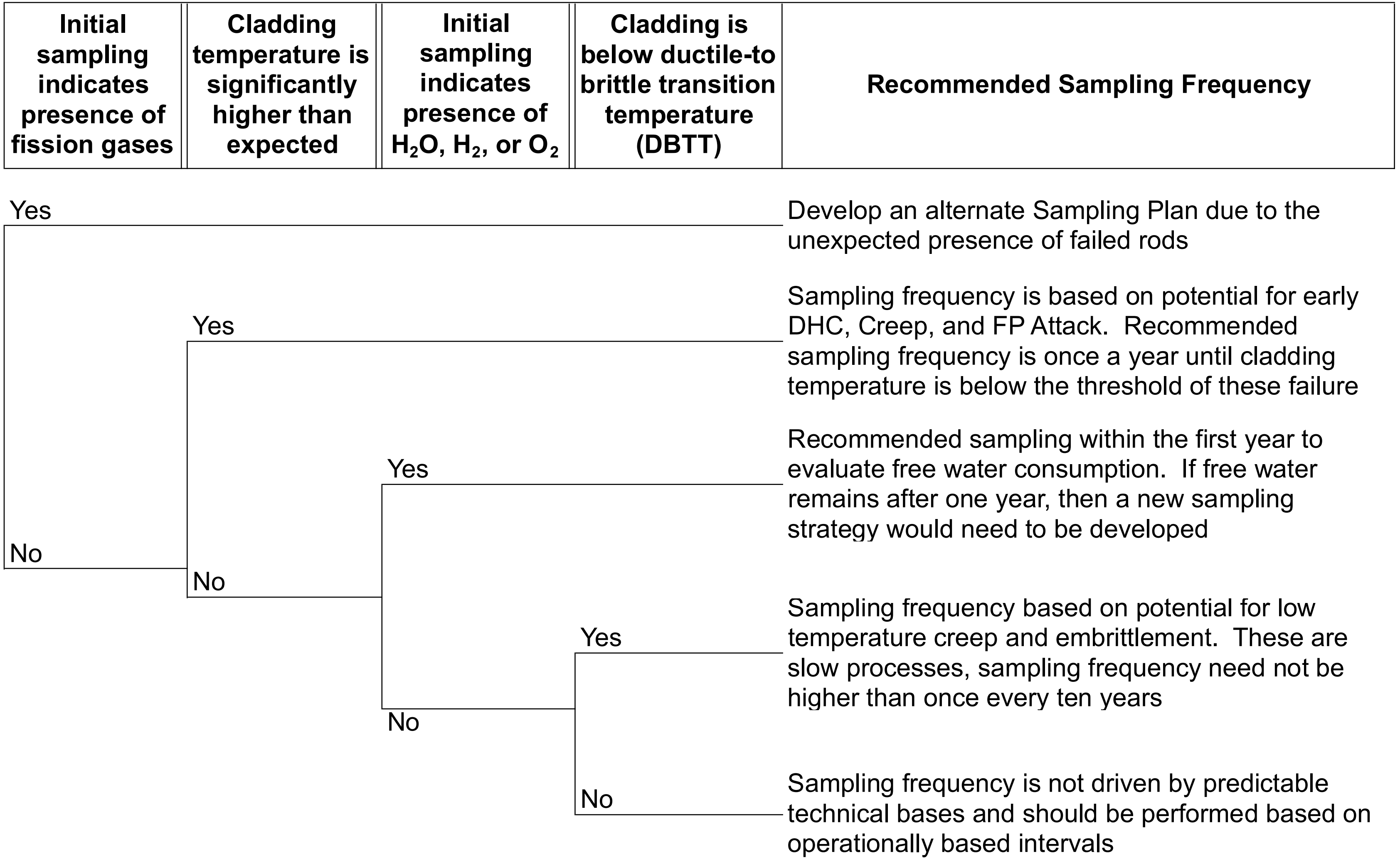
   - ***Can*** **provide total consumption rates of H_2O, H_2 and O_2**
   - ***Cannot*** **provide the fraction that is consumed by each component or the amount of degradation experienced by each component**

   - ***Can*** **indicate cladding breach and provide changes in total concentration of fission gases.**
   - ***Cannot*** **indicate number of failed rods or mechanism(s) that caused breach**

Gas Sampling Frequency Strategy

- **Adaptive**
  - **based on measured temperatures, initial (in-building) sampling, and one early sampling (within a year).**
- **If conditions are as expected**
  - **then the sampling frequency is not driven by a predictable technical basis, and an operationally based interval is recommended.**
- **Sampling strategy should be reevaluated if:**
  - **Fission product gases are detected**
  - **Cladding temperatures are above 400° C**
  - **≥0.25 volume percent water and/or oxygen is present at 1 year sampling**
  - **Any off-normal, accident, or natural phenomena event occurs**

Gas Sampling Frequency Strategy



Initial sampling indicates presence of fission gases	**Cladding temperature is significantly higher than expected**	**Initial sampling indicates presence of H_2O, H_2, or O_2**	**Cladding is below ductile-to brittle transition temperature (DBTT)**	**Recommended Sampling Frequency**

Develop an alternate Sampling Plan due to the unexpected presence of failed rods

Sampling frequency is based on potential for early DHC, Creep, and FP Attack. Recommended sampling frequency is once a year until cladding temperature is below the threshold of these failure

Recommended sampling within the first year to evaluate free water consumption. If free water remains after one year, then a new sampling strategy would need to be developed

Sampling frequency based on potential for low temperature creep and embrittlement. These are slow processes, sampling frequency need not be higher than once every ten years

Sampling frequency is not driven by predictable technical bases and should be performed based on operationally based intervals

One Proposed Operationally Based Sampling Frequency

- **Sample the cask a minimum of four times**
  - Shortly after loading
  - At about one year
  - Approximately three years after the one year sampling
  - At ten years prior to shipping the cask

- **If there are any indications of a fuel rod breach from the first sampling after loading, more samples may be taken while the cask is in the North Anna decontamination building.**